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Psychology

22 pages

Writing and Following Procedural, Descriptive, and Restricted Syntax Language Instructions[1]

John D. Gould, Clayton Lewis,[2] Curtis A. Becker[3]

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ABSTRACT: Two exploratory experiments compared the way people (with no experience in the use of computing systems) write and carry out natural language procedures, natural language descriptions, and instructions expressed in an artificial restricted syntax language. The results suggest that there is no single "natural" way that people write simple plans and instructions. Speed and accuracy of writing were about the same for all three approaches, although the linguistic characteristics differed greatly from approach to approach. While subjects were tolerant of ambiguity both in writing and in carrying out instructions, they often voluntarily employed restricted-syntax notation in their writing after being exposed to the notation. Subjects' accuracy in following detailed instructions was no greater than that in writing those instructions.

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Introduction

There are several general forms of expression that people can use in generating instructions for themselves, other people, or machines to follow. These include forms emphasizing a description of a desired object or state (e.g., "Get a list of employees over forty years of age who have five or more dependents") and forms emphasizing a procedure, or sequence of steps to be carried out, (e.g., "Go to the employee file. Take out the first folder. If the employee is over forty then..."). Instructions may be given in ordinary English or in an artificial language with a restricted syntax, such as a computer programming language or the special notation used in knitting instructions. Besides restricted syntax, these artificial languages have a restricted lexicon, a restricted semantic domain, and specialized conventions.

In designing computing systems to be used by non-programmers, questions arise about the merits of various forms for expressing instructions to the computer. Are descriptions more "natural" than prodecures? Do instructions expressed in a restricted syntax language take longer to write than instructions expressed in English? Do untrained persons prefer one form of expression over others? Which approach is most accurate? Does an individual use the same approach in related task environments? Can task environments be studied to determine, to a useful degree, the characteristics of people's linguistic productions? The experiments reported below were designed to permit these and similar comparisions among various forms of expression used by subjects on some simple tasks.

In the first experiment we asked subjects to write various kinds of instructions and observed the time taken to write the instructions and the adequacy of the instructions produced. In one condition subjects

were not constrained to use any particular form of expression; we were interested in the forms they would choose. In other conditions, subjects were required to write procedural instructions, descriptive instructions, or use a simple restricted syntax language. To provide a practical test of the instructions produced, each subject was given the instructions written by another subject, and she was then required to carry them out. For comparison, subjects also were asked to carry out instructions carefully prepared by experimenters. Speed and accuracy of performance were recorded.

In the second experiment we concentrated on subjects' preferences for forms of expression. We looked again at unconstrained expression, and also asked subjects to rate the naturalness and effectiveness of instructions of various kinds.

Experiment I

Method

Subjects. Subjects were fourteen general filing clerks employed by a local temporary manpower agency. They were generally middle aged (median = 44; range 21 - 63) high school graduates (one had only two years of high school and six had some education beyond high school) who sometimes worked part-time outside the home.

Design and Procedure. Two task settings were used. In Blocks subjects wrote protocols (this term refers to the material that subjects wrote) about figures made of colored cubes (children's blocks). Fourteen figures were used, including a horizontal row of eight blocks, a double staircase of twenty blocks, and a figure with a jagged base and irregular height containing 13 blocks. In Typing subjects wrote protocols about 6 x 6 figures of characters. Seven figures, all composed of

X's and blanks, and all having simple verbal descriptions, were used. For example, one figure had odd-numbered columns filled with X's and another had a diagonal of X's.

For each task setting a simple restricted syntax language was devised. For Blocks, subjects could write

START WITH _____
(Block color)

followed by a series of statements of the form

PUT _____ _____ _____
(block color) (spatial relation, e.g. "to the right of", "above") (block color)

All figures were designed so that they could be described unambiguously in this language. The typing language had only one statement:

HIT _____ _____.
(key, i.e., X, space, return) (times, e.g. 3)

Subjects were required to generate instructions and to follow instructions. In generating, a subject was given a figure and told to write a protocol of a particular kind. For example, she was told, "Please write a detailed description of this figure." Blocks figures were placed in front of the subject for these trials, while Typing figures were only described orally to her.[4] In following, a subject was given a protocol written by another subject and asked to build a figure from it.

Subjects wrote protocols under each of four different constraints, conveyed by the instructions of the experiment. Under the Description constraint a subject was told, "Please write a detailed description of this figure." Instructions for the Procedure constraint were, "Please

write a procedure, or plan, to build [or type] this figure." Under the Restricted Syntax constraint a subject was taught the restricted syntax language for the task and told to use it. The Neutral constraint instructions were intended not to restrict the form of the protocol. They were, "Please describe in writing how you would tell somebody else how to build or type this figure." As part of the instructions for each constraint, subjects were told that they must be specific about "the color and position of each block" in blocks (there were four colors), and "each filled and unfilled character space" in typing.

The sequence of events for a typical subject is shown in Figure 1. The ordering of events within brackets was balanced across subjects. Notice that every subject had one Neutral constraint trial before learning the restricted syntax language or seeing experimenter-written examples of it, and a second Neutral constraint trial afterwards. Except for the variations within the brackets, the order shown in Figure 1 was used for all subjects; all subjects worked on Blocks before typing. In following protocols written by another subject (8th through 12th events in Figure 1), each subject followed those written by the previous subject (a pilot subject was used for the first subject). The fourteen Blocks figures used were divided into two sets of seven which were given, respectively, to odd and even-numbered subjects, so that no subject would be following a protocol for a figure she had already seen. Within these sets, the assignment of figures to events was balanced across subjects.

Although subjects' performance was timed with a stopwatch by an experimenter, they were told they were not under time pressure.

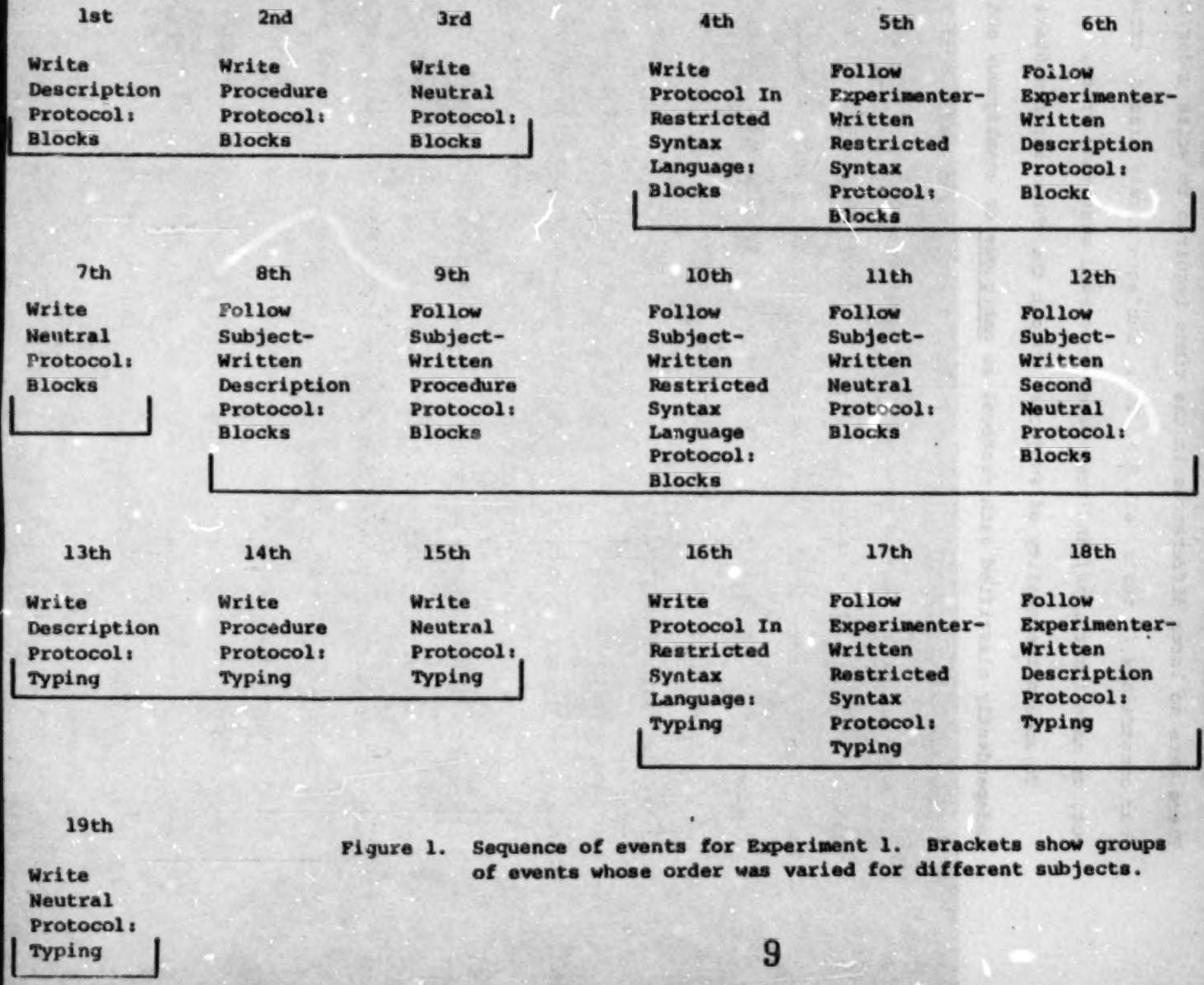

Figure 1. Sequence of events for Experiment 1. Brackets show groups of events whose order was varied for different subjects.

Results

Generating. The times for protocol generating are shown in Table 1. There were no large differences in the times required to write under the four constraints (F tests, all P > .10). Subjects rarely erased, crossed out, or made insertions, and they rarely reviewed what they wrote.

To assess the quality of subjects' output the three experimenters independently classified each protocol as ambiguous or unambiguous and, separately, as consistent or inconsistent. A protocol classified as ambiguous and consistent is one which (a) specifies more than one figure, and (b) one of which is the target figure. A protocol classified as unambiguous and inconsistent is one which (a) uniquely specifies just one figure, but (b) which is not the target figure. Table 2 shows the results of this classification.(5) There is not much difference in consistency under the various constraints, i.e. about 65 - 80% of protocols were consistent with the target figure under each constraint. As might be expected, Restricted Syntax protocols were less often ambiguous than the others (28% vs. 50%). The second Neutral constraint protocols were also less frequently ambiguous than the others, mainly because these protocols showed the influence of the Restricted Syntax language.(6) Subjects readily adopted the succinct, precise shorthand notations of the experimenters.

The two task settings seemed to make different demands on subjects. Mainly, there were many fewer ambiguous Typing protocols than Blocks protocols (26% vs 68%). Nearly all these Blocks' protocols contained ambiguities about the spatial position of the blocks(7). In Typing, explicit specification of the spatial position was usually not required. Comparisons among constraints look roughly the same for both tasks, however.

Table 1. Mean Times (Sec.) To Generate Protocols In Experiment 1. (Standard Errors Are In Parenthesis)

Task Environment	Procedure	Description	First Neutral	Second Neutral	Restricted Syntax
	Generating Constraints				
Blocks	185 (25)	215 (50)	185 (35)	175 (25)	190 (20)
Typing	215 (40)	255 (45)	210 (30)	190 (25)	240 (30)
Means	200	235	200	180	215

Table 1. Accuracy of Protocol Generation

	BLOCKS					TYPING				
	Procedure	Description	First Neutral	Restricted Syntax	Second Neutral	Procedure	Description	First Neutral	Restricted Syntax	Second Neutral
Unambiguous-Consistent	1	3	3	8	6	6	9	7	7	7
Ambiguous-Consistent	10	7	8	2	5	3	0	4	2	2
Ambiguous-Inconsistent	2	4	3	4	3	1	4	2	0	0
Unambiguous-Inconsistent	1	0	0	0	0	4	1	1	5	5
Totals	14	14	14	14	14	14	14	14	14	14

Table 3. Classification of Written Protocols

Judged Characteristics Of Written Protocols		ACTUAL INSTRUCTIONS: Procedure	Description	First Neutral	Restricted Syntax	Second Neutral	Totals
BLOCKS	Procedure	10	2	11	1	5	29
	Description	4	12	3	0	3	22
	Restricted Syntax	0	0	0	13	6	19
TYPING	Procedure	13	7	12	1	4	37
	Description	1	7	2	0	0	10
	Restricted Syntax	0	0	0	13	10	23

Individual subjects varied over a wide range in accuracy. Of the twelve protocols they wrote, two subjects wrote eight unambiguous-consistent protocols and two wrote only one such protocol. Subjects were not reluctant to write protocols (as we thought they might be), although in Typing a few did state they knew how to type a figure but not how to write about typing it.

The protocols were also classified by the experimenters as Procedure-like or Description-like according to their linguistic characteristics.(8) A protocol was classified as a Procedure if it contained sequential executable steps, action verbs or imperative mood. It was classified as a Description if it referred to major components of the target figures' structure, was in the passive voice, or used existential verb constructions. In addition, protocols which showed clear similarity to one of the Restricted Syntax languages were classified as Restricted Syntax. Table 3 shows the results of this classification. Most protocols (81%) were linguistically characteristic of the expressional constraints under which they were written; that is, subjects could follow instructions and readily change their mode of expression. Most Neutral constraint protocols and even several Description-constraint protocols were classified as Procedure-like. Many of the second Neutral constraint protocols, written after exposure to the Restricted Syntax language, incorporated the Restricted Syntax language, and were so classified.(9)

Following. Times required to follow experimenter-written protocols are shown in Table 4. As might be expected, following is faster than writing (cf. Table 1), (F (1,13) = 22.16; $P < .001$). Table 4 also shows the accuracy

Table 4. Time And Accuracy In Following Experimenter-Written Blocks And Typing Protocols In Experiment 1. Each Cell Is Based Upon 14 Subjects.

		Natural Language Descriptions	Restricted Syntax Procedures
BLOCKS	Mean Time (Sec.)	90	75
	% Correct	9/14	9/14
TYPING	Mean Time (Sec.)	140	140
	% Correct	11/14	11/14

Table 5. Accuracy Of Following Experimenter-Written And Consistent Subject-Written Blocks Protocols In Experiment 1.

	Consistent Subject-Written Protocols	Experimenter-Written Protocols
No. Target Figures Correctly Constructed	31	18
No. Attempts	53	28
Percent Correct	.59	.64

Table 6. Accuracy Of Subjects' Following The 53 "Consistent" Subject-Written Protocols (i.e., Those 53 That Correctly Described The Target Figures, Among Others)

(A)
Instructional Constraint

	Procedure	Description	Restricted Syntax	First Neutral	Second Neutral	
No. Correctly Followed/ No. of Protocols	8/11	5/10	8/10	8/11	7/11	$\frac{36}{53}$

(B)
Classification of the Written Protocols

	Procedure-Like	Description Like	Restricted Syntax	
No. Correctly Followed/ No. of Protocols	18/23	9/16	9/14	$\frac{36}{53}$

with which the experimenter-written protocols were followed. Notice that subjects were far from perfect in following these carefully prepared protocols. Errors fell mainly into three classes: in Blocks, skipping an instruction or confusing spatial relations; in Typing, inserting extra rows or columns. As shown in Table 5, this same level of accuracy resulted when subjects followed protocols written by other subjects which were consistent with the target figures even though these subject-written protocols were often ambiguous. Apparently subjects were able to disambiguate these protocols using contextual cues and their knowledge of the task setting. As stated above, the block figures that subjects reconstructed in following were similar but different from those they had previously worked with.

Accuracy in following subject-written protocols was not dramatically affected by the instructional constraint under which they were written (Table 6a) or gross linguistic characteristics of the protocol (Table 6b), although procedural protocols seem to have some advantage over descriptive ones.

Discussion

Two main conclusions emerge from the generation results. First, the speed and accuracy of generating protocols does not seem to depend much upon the instructional constraints imposed. The task environment of these two relatively simple tasks greatly affects accuracy, however. Second, under the Neutral constraint subjects tend to choose procedure-like expressions -- in fact, they even adopted features of the procedural Restricted Syntax language. We had thought that procedures might be followed more quickly and perhaps more accurately than descriptions because a person does not have to generate his own sequence of operations prior to performing them, but this was not the case with these experimenter-written protocols.

In comparing generating and following, it is interesting to note that while building a figure from a protocol is faster than writing a protocol for that figure, the accuracy of the two processes is about the same in the sense that about 75% of Subject-generated Blocks protocols were consistent, whereas 64% of experimenter-written Blocks protocols were followed correctly. Why should this be, given that subjects have much more experience following protocols (assembly instructions, recipes) than writing them? It may be that subjects were less careful than usual while following protocols in this experiment. Even though they were able to disambiguate protocols in these task settings, perhaps subjects normally rely even more on their knowledge of task settings to guide themselves toward their goals. On the other hand, home economics teachers tell us that they observe error rates at least this high when students and adults attempt to follow cookbook recipes.

The tendency of subjects to write procedure-like protocols under the Neutral constraint has at least two interpretations, both of which may be correct. One is that subjects have a strong tendency to write procedure-like protocols which they generally express unless prevented from doing so. Another is that the Neutral constraint as stated was not really Neutral: it encouraged subjects to write procedural protocols. Experiment 2 investigates the issue and attempts to discover subjects' own views on the desirability of various forms of expression.

Experiment 2

Method

Subjects. Subjects were eleven female and one male liberal arts college students with little or no experience in using computer systems.

Table 7. Criteria used in ranking protocols in Experiment 2

Rank according to the way you word ordinarily tell a friend about this figure if this friend wants to know about it.	Rank according to the best way to tell a friend about this figure if this friend wants to know about it.
Rank according to the way you would ordinarily tell a friend about this figure if this friend must use this information to identify, or pick out, this figure from among several other block figures.	Rank according to the best way to tell a a friend about this figure if this friend must use this information to identify, or pick out, this figure from among several other block figures.
Rank according to the way you would ordinarily tell a friend about this figure if this friend must use this information to reconstruct the figure.	Rank according to the best way to tell a friend about this figure if this friend must use this information to reconstruct the figrue.

Procedure. Experiment 2 consisted of two phases, writing and ranking, carried out in that order by all subjects. In the writing phase each subject was asked to write a protocol for each of three Blocks figures. Half of the subjects were given the Neutral constraint instructions used in Experiment 1: "Please describe in writing how you would tell somebody else how to build this figure. You must be specific about the color and position of each block." The other subjects were told, "Please write how you would describe this figure to a friend. You must be specific about the color and position of each block." It was felt that this instruction might encourage production of description-like protocols.

In the ranking phase each subject was given a set of five protocols taken from Experiment 1 and asked to rank-order them according to one of the six specified criteria shown in Table 7. All protocols within a set described a single Blocks figure, placed in front of the subject. The five protocols to be ranked were a natural-language Procedure protocol written by a subject in Experiment 1, a Description protocol and Restricted Syntax protocol from the same source, and a Description protocol and Restricted Syntax protocol written by the experimenters. The subject-written protocols were selected from among those rated unambiguous-consistent in Experiment I or were revised slightly to bring them to that standard. Each subject ranked six different sets of protocols, one for each of the six criteria of Table 7. Each set of protocols was about a different Blocks figure. The order in which criteria were used in ranking, and the pairing of figures and criteria, were balanced over subjects, except that the three "ordinarily" criteria (see Table 7) always preceded the three "best way" criteria.

Results and Discussion

Writing. As in Experiment 1, the "Neutral" constraint instructions produced mostly procedure-like protocols (see Table 8). College students did not differ much from middle-aged file clerks in this regard. The description-biased instructions, on the other hand, produced only description-like protocols. Thus the choice of form of expression by subjects is easily controlled by instructions which do not specifically dictate the form to be used. This does not mean that subjects have no general tendency to generate procedure-like protocols; it only means that this tendency can be counteracted by fairly mild instructions. The different effects of the two sets of instructions might arise in two ways. It may be that subjects felt that the purpose for which the protocols were to be constructed was different under the two instruction sets, and chose the most effective form of expression in each situation. In this case, choice of form of expression depends on the particular task pursued. On the other hand, it may be that subjects saw no important difference in the purpose of the protocols but interpreted the instructions as demanding a particular form of expression. In this case some limit may be placed on the strength of preference in form of expression subjects may have, since the instructions made no direct demand.

When these protocols were examined for ambiguity and consistency, as in Experiment 1, those written under the "Neutral" constraint were less often ambiguous than those written under the Description-Biased instructions, as shown in Table 9. This is consistent with the finding in Experiment 1 that procedure-like protocols were less often ambiguous than description-like protocols.

Table 8. Classifications Of Protocols Written By Subjects In Experiment 2.

	"Neutral" Constraint Instructions	Description-biased Instructions
Procedure-Like	11	0
Description-Like	7	18

Table 9. Accuracy Of Protocols Written In Experiment 2

(A)

For Description-Biased Instructions

	Consistent	Inconsistent	
Unambiguous	1	2	3
Ambiguous	10	5	15
	11	7	

(B)

For "Neutral" Instructions

	Consistent	Inconsistent	
Unambiguous	8	2	10
Ambiguous	6	2	8
	14	4	

Ranking. Table 10 shows the average ranking of protocols by type. The "ordinary" and "best way" criteria did yield different rankings. Subject-written procedures and descriptions were, over-all, most preferred; restricted syntax protocols were least preferred. The purposes specified in the criteria did affect rankings, however, (Purpose x Protocol Type interaction $F(8,88) = 3.16$ $p < .01$.) subject-written procedures were given highest rankings under the general "to know about the figure" criterion. Descriptions were preferred under the "to identify" criterion. As far as these subjects were concerned, then, there is no single preferred form of expression. Rankings such as these may have limited validity in predicting how people actually generate instructions: the experimenter-written Restricted Syntax protocols were given low rankings, while in Experiment 1 subjects frequently chose to use features of the Restricted Syntax language in generating protocols.

Summary and Conclusions

The key results of Experiment 2 are two. First, seemingly small variations in instructions can lead to large variations in the form of expression that people use, even though the same goal is sought in all cases. Subjects easily varied the surface structures of their protocols. Second, when asked their preference for protocols using different forms of expression, subjects showed different preferences under different task demands.

The significance of all the findings, based upon simple tasks, to the designers of computer systems for non-programmers is that there is no single

Table 10. Mean Rank Order Results for Experiment 2 (1 = Most Likely to Use; 5 = Least Likely to Use).

	Type of Protocol				
Purpose	Subjects' Procedures	Subjects' Restricted Syntax Language	Subjects' Descriptions	Experimenters' Restricted Syntax Language	Experimenters' Descriptions
Know about	2.25	3.58	2.62	3.71	2.71
Identify	3.04	3.88	2.46	3.92	1.71
Reconstruct	1.71	3.63	2.96	3.96	2.78
	2.33	3.67	2.33	3.86	2.78

"natural" form of expression. Mild variations in task environment and expressional constraints lead to large variations in the way subjects express themselves. In designing a hypothetical computer system dealing with Blocks figures, for example, one could not just find the "natural" way of referring to them and implement it, since there is not a single natural way. Human linguistic and cognitive systems are better characterized as adaptive than as having strong "natural tendencies." Discovering "natural ways" people think and speak has ethological value and sometimes psychological value, but may have little value for systems design.

The acceptance of restricted-syntax languages by subjects strikes an encouraging note. Whereas they generally showed low preference for them as a way of expressing instruction (Experiment 2), when called upon to express instructions themselves, subjects readily and sometimes spontaneously used restricted syntax (Experiment 1). So it may not always be necessary or desirable to avoid such language restrictions in system design, even when it is possible to do so. Well designed restricted-syntax languages that map well onto a problem can provide thought-templates for a person describing or expressing that problem. There are major distinctions between a "natural language" computer system and a "natural-like" computer system that uses a restricted syntax language system that may bear little resemblence to "natural language". Most of the behavioral and system advantages favor the "natural-like" approach, at least for the next decade.

Care should be taken in generalizing these conclusions. Protocols were elicited under artificial conditions in which subects may have been concerned more with the form of protocols generated than with their effectiveness. If subjects really had to use their protocols to accomplish something more,

their choices might be different. The task settings used were very simple, much simpler than the simplest programming task domains. Subjects were initially naive about the tasks they were undertaking; users of a hypothetical computer system might be expected to know more about what they are trying to do, and this knowledge might bring with it ideas (perhaps useful, perhaps interfering) about reasonable forms of expression. These limitations granted, these findings may at least suggest that questions about form of expression will not have simple answers.

FOOTNOTES

1. We thank John Thomas, K. William Scholz, and Stephen Boies for commenting on versions of this manuscript.

2. Now at Psychology Department, University of Michigan, Ann Arbor, Michigan.

3. Now at Psychology Department, University of Oregon, Eugene, Oregon.

4. Subjects could have used the descriptons, by repeating them, as their protocols in the generating conditions, but this was done only twice.

5. Sixty percent of the 70 generated Blocks protocols were judged the same way by all three experimenters. All but 4 of the 70 were resolved by majority decision. Two experimenters judged the 70 generated Typing protocols and initially agreed on 80%.

6. Performance with the Restricted Syntax language may have been helped by a practice effect, which occurred in Blocks but not in Typing. About three times more Blocks protocols were unambiguous-consistent if they were the fourth or fifth ones written than if they were among the first three written.

7. These ambiguities took several forms: (a) No specification of position, e.g., "Next ... is two red blocks, then two yellow blocks." (b) Use of ambiguous words to specify position, e.g., "next to", "beside", "across from"; ("next to" was usually intended to mean "to the right of", but sometimes to mean "above"). (c) Variable use of imprecisely defined nouns, e.g., "tiers", "layers", "lines". (d) Use of traditionally defined terms in a non-traditional way, e.g., "row", "column". (e) Ambuguities arising from more than one possible location for a block, e.g., "Put a blue block on top of red" when there were two different red blocks with no blocks on top of either. This error mainly occurred with the Restricted Syntax language. (In designing the block figures, care was taken so that protocols could be generated without forcing this type of ambiguity). (f) Imprecise specification, or no specification, of the relation within a "sub-assembly" of blocks, or between sub-assemblies, e.g., "in front of that, using the same color procedure as above, place three more blocks". Note that this example is analogous to a DO loop operation, although neither bound of the loop is specified. Perhaps the reason that ambiguities were concerned with spatial position is because position demands a reference to a previous block, whereas color and number do not.

   Ambiguities in Typing protocols were due to (a) linguistic confusion, e.g., use of the word "blank" as an adjective to specify an empty cell

and as a verb to specify skipping a cell; (b) contradictions, e.g., a summary statement about the entire figure contradicted earlier or subsequently written details; (c) unclear specification of counting or looping, such as "go back to the beginning of the line"; and (d) incomplete specifications. In both tasks subjects tended to specify precisely the number of interations in a looping operation but not the bounds.

8. These classifications were done independently by each experimenter, who was not aware under which instuctional condition each protocol was written. In Blocks, 81% of the 70 protocols were categorized the same way by all 3 experimenters, and all but two were resolved by majority decision. The agreement among the three experimenters on Typing was low. Fifty-nine percent of the 70 protocols were classified the same way by all three experimenters, and all but 2 were resolved by majority decision.

9. The mean number of words and abbreviations was about the same under all instructional constraints, varying from 50-70 for blocks and from 35 to 55 for Typing. These rates of 12 to 20 words or abbreviations per minute are about one-half the rate of writing memorized material (30 to 40 words per minute). Procedure protocols typically used transitive verbs ("place", "put", "lay", "build" in Blocks; and "type", "make", "start", "return" in Typing) or similar special constructions ("start with", "go back to" in Blocks and "leave empty" in Typing). Description protocols typically started with existential constructions ("There are", "The figure contains"), contained passive constructions ("...is filled with"), or contained no subject-verb construction ("Four grey blocks one on top of the other...". Some subjects spontaneously reported that the Restricted Syntax language made their task easier (contrary to their acutal time scores) because they did not have to "put things in their own words". Twelve of the 28 Blocks Procedure and Description protocols began with an initial general summary sentence, followed by specifics about parts of the target figures. None of the Typing protocols began with a summary statement. Most subjects drew some pictures in Typing but no pictures in Blocks.